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PAPER

Development and Impact of a Mobile Application that Allows Users to Track Their Location on an Educational Institution Campus, a Simulation Study

Carlos Andrés Tavera Romero[1](✉), Patricia del Rosario Segovia de Maya[1], María Fernanda Díaz Velásquez[2], Diego Fernando Pérez Carvajal[1]

[1]COMBA R&D Research Group, Faculty of Engineering, Universidad Santiago de Cali, Santiago de Cali, Colombia

[2]GIEIAM Research Group, Faculty of Engineering, Universidad Santiago de Cali, Santiago de Cali, Colombia

carlos.tavera00@usc.edu.co

ABSTRACT

This research study aims to solve user location issues within the campus at an educational institution. As this campus comprises a large number of places and departments, users often get confused about how to reach a specific location. To address this problem, the "Ubícate" ("locate by yourself" in Spanish) application was developed following the CDIO methodology, which encompasses four creative process steps: conceive, design, implement, and operate. The "Ubícate" app provides users with information on places of interest such as schools, departments, halls, auditoriums, and sports venues, offering a visual reference of available locations through 360-degree images. The application also uses Google Maps to track user location within the campus, thus marking a reference route between university gates and the different locations available, in addition to providing information on university-sponsored events. In this paper, Section 2 describes the methodology and each of the stages that were addressed in the following sections. Section 3 presents the development itself and the data used for the purposes thereof. Next, Section 4 reveals the results from this study. Later, Section 5 assesses these results and the findings from the study. In Section 6, our conclusions are discussed. Finally, Section 7 lists topics for future research. The application did indeed contribute to improving the attendance of the academic community at events. Where the application was used, the first-hand perception of visitors and their own was very positive and enhanced the institutional image and sense of belonging. The contribution of this study consists of presenting a mobile application as a solution from three approaches: the technical aspects for application development, the business vision to satisfy the user's needs, and the end user's perception. All three approaches provide a technical reader, an entrepreneur, or an end user an overview of a scalable solution to different types of implementations in different types of businesses that require indoor location through the use of technologies in mobile applications. The mobile application performs the location indoors using the Google Maps platform, allowing a more agile development in implementing the APP.

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KEYWORDS
mobile application, geographic information systems, academic institutions, georeferencing, 360 views

1 INTRODUCTION

1.1 Theoretical framework

The development of this research study starts by querying data of the Global Navigation Satellite System (GNSS) that have already existed for several years and are currently used in multiple applications. GNSS technology comprises several outdoor positioning systems, such as Global Positioning System (GPS), GLONASS, Galileo, and BeiDou, whose services are available everywhere on Earth. However, the accuracy of outdoor positioning systems is often poor when GNSS signals are blocked in the environment. These environments include spaces that are fully or partially hidden by building structures, dense urban areas surrounded by tall buildings, and underground environments [1].

The GPS is a service owned by the United States government that provides users with positioning, navigation, and timing information [2]. The GPS system was required to track user location when using the application. Ultimately, [3] describe the theory, algorithms, and applications of the GPS.

Hence, indoor mapping solutions require more reliable technology than satellite navigation services. For example, several studies [4] [5] [6] [7] use other mechanisms to enhance the reliability of the navigation system. Still, this study will only focus on satellite navigation services and outdoor user locations.

The Flutter framework [8] created by Google is a tool for the development of native iOS and Android mobile applications. As mentioned throughout the literature, these are the most commonly used mobile operating systems in the world [9]. Flutter uses the Dart language [10] [11], an optimized client development language for building multi-platform applications whose easy code interpretation expedites and facilitates the operation of applications.

The Google Maps platform [12] allows developers to create applications using Google Services that provide maps, geolocation, and coordinates in real time. This research study used these tools to develop the application, plot routes, and display user locations.

A first positive impact is decisive for constructing a sense of belonging and a good institutional image. In this sense, applications, especially mobile ones, as communication tools are a resource that can help. Significantly, an application that guides the academic community on a vast campus can avoid frustrations. These types of tools can be taken as a way to increase students' awareness of the educational benefits that the integration of mobile technologies can bring to formal education [13].

1.2 State of the art

User location tracking has also been assessed at other universities. For example, [14] identified the shortcomings of the GPS indoors and [15] used Geographic Information Systems developed at Wuhan University in China to create a campus navigation system.

Furthermore, [16] proposes an Android prototype for an aquatic tourism application that combines augmented reality with geolocation to demonstrate how the real world and the generated world can complement each other to help expand tourism knowledge.

In the two University of Jadavpur sites in India, [17] proposed the development of a mobile application using Google Maps and the Android SDK to reduce user frustration and confusion within the campus.

Aimed at improving current location and target location tracking through GPS technologies and Google Maps in Thailand, [18] developed a comprehensive navigation system composed of a network application running on web browsers using PHP, AJAX, JAVA, and JavaScript technologies.

1.3 Goals

Within this context, this study seeks to create a mobile application based on four steps:

1. Assessing the system requirements for the development of a mobile application that tracks user location within campus.
2. Designing the system architecture as per the requirements assessed.
3. Developing the application based on the results obtained from the Analysis and Design stage.
4. Conducting user tests, proposing improvements in future updates.

2 RESEARCH PROBLEM

2.1 Methodology of the literature review

To identify the technologies used in the development of a mobile interior location application, a literature review was constructed with four stages: first stage, the establishment of research questions; second stage, design and implementation of the search for information using the Prisma methodology; third stage, analysis of information and synthesis in a table; and fourth stage, discussion and interpretation of the information in the table, answering the research questions (See Table 1).

2.2 Bibliographic search and selection criteria

In the first stage of the proposed methodology, researchers defined the following research questions (RQ), (See Table 1).

Table 1. Research questions (RQ)

RQ#	Research Questions	Description
RQ1	What papers describe current software and hardware technology tools for developing indoor location solutions using mobile apps?	Identify if the description of the technological tools found in the papers is done in low, medium or high grade. Comparative table of articles. What are the technological tools recommended in the papers for the indoor location when developing an APP?
RQ2	What papers describe the business vision regarding the benefit of using APP?	Identify if the description of the business vision found in the papers is done in low, medium or high grade. Comparative table of articles.
RQ3	Does the APP show the user's perception?	Identify if the description of the user perception found in the papers is done in low, medium or high grade. Comparative table of articles.

Step 2 identifies the search keywords, the selection of databases, and the search formula applying the search in the selected databases. The criteria used to search and select papers based on the Prisma methodology are described below.

In the review of articles, the following keywords: "mobile app" and "indoor location" were used, searching for title, abstract, and keywords. The query was made in the international database Scopus, without limitation of years, without limitation in language, and using Boolean operators AND and OR (Equation 1).

TITLE-ABS-KEY ("mobile app") AND TITLE-ABS-KEY ("indoor Location") (1)

The search process was carried out in September 2023 using the Prisma methodology in four phases. In the first phase, nine documents were identified using the search criteria "mobile app" and "indoor location" in title, abstract and keywords. In the second phase or screening, the correspondence of the nine documents found for investigation was reviewed, analyzing the summaries and introductions of the documents.

In phase three, eight documents corresponding to two article-type publications and six proceedings were chosen, deleting [Design and Implementation of intelligent Home monitoring System based on mobile robot] for not corresponding to the research objective. Finally, eight documents published between 2012 and 2023 in English were obtained.

Table 2. Comparative table of the documents found and the current paper, regarding the research questions

Paper Name	Publication Year	Describe Current Software and Hardware Technology Tools for Solution Development	Business Vision Regarding the Benefit of the Use of APP	Shows Impact About User
Museum Guide, a Mobile App	2012	LOW	MEDIUM	HIGH
Business Intelligence by Connecting Real-Time Indoor Location to Sales Records	2014	HIGH	LOW	LOW
Beacons and BIM Models for Indoor Guidance and Location	2018	HIGH	MEDIUM	LOW
Towards an Integrated Hybrid Mobile Application for Smart Campus Using Location-Based Smart Notification	2019	MEDIUM	MEDIUM	HIGH
A new concept of smart shopping platform based on IoT solutions	2020	LOW	HIGH	LOW
Solomon – social local indoor enhanced shopping platform	2020	MEDIUM	HIGH	MEDIUM
Enhancing micro-location accuracy for asset tracking: An evaluation of 2 fingerprinting approaches using 3 machine learning algorithms	2022	HIGH	MEDIUM	MEDIUM
Robust Indoor Location Identification for Smartphones Using Echoes From Dominant Reflectors	2023	HIGH	MEDIUM	MEDIUM
Development and Impact of a Mobile Application that Allows Users to Track Their Location on an Educational Institution Campus, a simulation study	2024	MEDIUM	HIGH	HIGH

As shown in Table 2, eight documents published from 2012 to 2023 were found according to the search criteria and research questions described in the methodology.

Table 3. Comparative table of the found documents and the current paper, regarding the applications of the APPs and a brief description of the article's theme focused on the review's interest

Paper Name	Observations	Application
Museum Guide, a Mobile App	Explain the functionality of the APP, not its implementation technology.	Museum Guide
Business Intelligence by Connecting Real-Time Indoor Location to Sales Records	Use the fingerprint of the intensity of the WiFi signal for location.	Business Intelligence
Beacons and BIM Models for Indoor Guidance and Location	Use building information models.	Users' movements inside a public building
Towards an Integrated Hybrid Mobile Application for Smart Campus Using Location-Based Smart Notification	Meeting room booking management application which utilizes an indoor location-based service using WiFi fingerprints to implement smart notification feature into the app to minimize or even eliminate the possibility of interruption overload that are often experienced by users of mobile application caused by the sheer amount of notifications.	Smart campus
A new concept of smart shopping platform based on IoT solutions	Presents an architecture for developing smart shopping solutions covering the image processing techniques used to generate digital maps, the internal location of the smartphone using BLE beacons, and internal routing techniques for finding stores in a mall.	guide and educate customers during shopping activities for the use of smart mobile applications
Solomon – social local indoor enhanced shopping platform	This paper presents a solution designed to improve customers' shopping experience in physical stores by connecting different technologies and data sources.	Customers' shopping experience
Enhancing micro-location accuracy for asset tracking: An evaluation of 2 fingerprinting approaches using 3 machine learning algorithms	Presents an indoor location system that uses BLE beacons and iPhones. A real-time context aware solution using BLE beacons, efficient fingerprinting and machine learning algorithms for indoor user/asset tracking.	Asset Tracking
Robust Indoor Location Identification for Smartphones Using Echoes From Dominant Reflectors	It proposes a new technique using acoustic signatures, which are derived from the mobile device by emitting a beeping signal and selecting its echoes created by dominant reflectors, as a robust fingerprint for location identification.	location identification under various real-world scenarios.
Development and Impact of a Mobile Application that Allows Users to Track Their Location on an Educational Institution Campus, a simulation study	For the development of the APP use the Flutter Framework with the Dart language and the google maps platform for maps, geolocation and coordinates in real time.	Campus university location

2.3 Discussion of results from Tables 2 and 3

Discussion of results from Table 2. The document that is being presented shows from three approaches the proposed location solution: from the technical aspects of developing the location application on a university campus, from the business vision to satisfy the user's needs, and from the perception of the end user. These three approaches provide a technical reader, entrepreneur, or end user with an overview of a scalable solution to different types of implementations, different types of businesses that require indoor location through the use of technologies in mobile applications. Therefore, the target audience for the article are: institutional well-being, technological management departments and marketing leaders in educational institutions or the business sector.

In Table 2, 50% of the papers found in the review give high importance to the description of current software and hardware technological tools for developing the solution, focusing on technologies that improve location accuracy in interior spaces, including the technical solution, artificial intelligence tools, acoustic signatures or architectural modeling of spaces (Building Information Model (BIM) is a 3D detailed geometric description).

Only 37.5% of the documents found in the review describe to a high degree information regarding the business vision that, through the use of ICT, adjusts its business models to improve customer service, seeking to increase their productivity. Finally, 37.5% of the documents found describe to a high degree the perception or impact on the end user.

Discussion of results from Table 3. Here the different technologies proposed in the articles for indoor location were presented. The technologies mentioned are the following: WiFi fingerprints, building information models, image processing techniques used to generate digital maps, the internal location of the smartphone using BLE beacons, machine learning algorithms and acoustic signatures.

In the case of the Ubicate USC APP, different technologies are used with the use of the Google Maps platform that uses satellites to detect our location through smartphone GPS. Google Maps also integrates the WiFi networks to which we connect and accesses cell phone towers to identify our location.

Table 3 shows the different applications proposed in the articles to use APP in an interior location, such as: smart businesses, location in shopping centers, guides in museums, among others. This broadens the vision for new markets, business models and new services.

Review conclusion. The inclusion of information technologies and the use of mobile phones allow the creation of new services and new business models, strengthening customer service and the end user's satisfaction level through the APP for indoor location. A mobile application that allows tracking indoor locations is a scalable solution for different uses and services. The Google Maps platform is recommended for more agile development in implementing the APP. Artificial intelligence on the Google Maps platform will facilitate precision in interior location and other functionalities for the end user in the App.

2.4 Research context

The campus location solution using a mobile application considered universities as companies that use technology to improve their processes and services [19] and that students enjoy using mobile devices as it is an intelligent device that answers their needs [20].

3 METHODOLOGY

3.1 Methodology description

For the development of the "Ubícate" mobile application, we used the CDIO methodology: Conceive, Design, Implement, and Operate [21] [22] [23] [24].

3.2 Methodology stages

Conceive. In the Conceive or Analysis stage, client requirements or needs are gathered. These requirements are used to assess system requirements and to draw up the architectural design of the application.

Design. In the second stage, the selection of the requirements or goals derived from the system is conducted. This will allow us to assess alternative application designs, select initial layouts, and then develop prototypes considering the different operation, maintenance, reliability, security, durability, evolution, and improvement requirements.

Implement. During the third stage, the designs created for the development of the application are implemented using the selected tools, describing the programming language, system development, hardware and software integration, the interactions with the necessary resources, and application functionality.

Operate. As part of the operation or testing stage, once the application has been completed, two tests were carried out:

General test. Functional end-user testing is conducted to determine whether the application actually solves the problems posed.

Location simulation. With a group of students, the unification experience on campus was simulated; the time required by the students was recorded and analyzed.

4 DEVELOPMENT

4.1 Introduction to the development process

A mobile application was developed as a useful tool to track user location within the campus at an educational institution. For these purposes, we used the CDIO methodology because it allows the work team to conduct the specific steps for each stage, starting from the initial requirements to the final tests.

4.2 Development implementation

Execution of the conceive stage. In the first stage, user requirements are gathered, collected, and assessed. In addition, the architectural pattern required for the development of the requirements is defined.

Execution of the design stage. In the design stage, we used the Model-View-ViewModel (MVVM) pattern, which is characterized by decoupling the user interface from the application's logic as much as possible. In addition, we developed the use case diagram for the functional requirements of the application.

For application performance purposes, we decided to use a NoSQL database. Here we used Firestore from Google [25] because it provides scalability, adaptability, facilitates schema modification, and optimizes record queries, in addition to providing a service for making Rest requests to the database. Furthermore, a general model was proposed for building, schools, departments, and common area information.

Execution of the implement stage. At this stage, the architecture was implemented. We started developing the application using the Flutter framework and determined the dependencies required for proper operation of the application. Some of these dependencies identified are finding a provider for consuming external services, such as database information, obtaining coordinates for plotting a route that guides users to their destination, and fetching information from the event repository in the event information system of the educational entity. In the case of the institution where the application was tested, it is called Peewah platform and is an educational scenario planning tool [26].

Together with the Flutter framework, the Dart programming language manages a class structure wherein each of the functionalities can be separated into a different class, known as a Widget. In turn, the classes can have children or sub-classes, or extend the functionalities from other classes. Both Dart and Flutter comply with the object-oriented programming paradigm and optimize the development.

Along with the architecture, system development generates a clean code wherein a view is managed for each screen displayed to the user. The logic from each view is separated through different models that control information flow and allow this information to pass from one view to another if required. Service providers are generated at a global scale, which creates a Singleton pattern and prevents the application from making excessive resource calls, in addition to fostering fast application operations and separating the business logic from the user's view.

The Google Maps platform displays maps and the user's location in real time. For this, users are asked to activate GPS services on their phones and allow the application to use location services.

For plotting routes, we collected the geographical coordinates at the educational institution and assessed the required points for each route. Then, these points are processed by drawing a line between each point and drawing this line on the campus map.

A GoPro Fusion camera was used to capture 360-degree images of the buildings, schools, departments, and common areas. These images are stored in the Google Cloud Storage service with a reference link in the database that supports requests for displaying images to users.

Implementation challenges and solutions

1. One of the goals of the Ubícate application is to be accessible to the entire academic community. Therefore, the software must be compatible with iOS and Android operating systems. The application must process 360 images and maps. Subsequently, the researchers suggest developing a native application to optimise the devices' resources. For the Android operating system, developers can choose between Oracle's Java or JetBrains' Kotlin languages. Meanwhile, for iOS, Apple's Swift is available, but opting for it would considerably extend development time. Therefore, the researchers opted to utilise Google's Flutter SDK and its Dart programming language, as it offers the opportunity to develop native applications for both iOS and Android without the need to duplicate development efforts.

2. After selecting Flutter, the researchers proceeded to choose the code that would enable the display of maps. They had a variety of choices, including the Mapbox plugin, OpenStreetMap, and Google Maps APIs. They ultimately went with Google Maps due to its compatibility, integration and maintainability with Flutter, as choosing an alternative could have led to time-consuming installation procedures or affected the application's performance through non-Google software updates.
3. Accuracy issues were encountered when utilising GPS in indoor localisation due to the signal being impacted by buildings and other structures. To supplement geolocation via WiFi and Bluetooth, other technologies were considered, however, this would demand further development and a larger infrastructure. Instead, strategic points and entrances to pivotal buildings along each route were assigned coordinates as a solution. This enabled the storage of route images for mobile device users who lacked a connection.

Execution of the operate stage.

Execution of general test. In the last stage, the application package was generated and made available to different people on campus, considering whether they owned iOS or Android devices. After they had used the application, they were asked to respond a survey to validate the usability of the application and their user experience. The survey questions were:

- Do you think that an application is required to track your own location within campus?
- Did the app help you find your way around campus?
- From 1 to 5, how was your experience using the application?
- Would you recommend the app to your colleagues?
- What other features would you like the app to have?

At the end of the Operation stage, to verify the application impact, we compared the number of absences and delays in academic events in 2018 and 2023. We did not consider the period 2020–2021 due to the confinement of the pandemic.

The application was tested in 64 spaces with a capacity between 50 and 1000 assistants.

Location simulation. Specifically, a location simulation was carried out using the Ubícate application.

A group of 300 college students was randomly chosen to simulate the campus location experience, with or without the Ubícate USC mobile app. Then, a selection filter was made for participants in the simulation, inquiring about whether they were unaware of their location on the campus and the range of places shown by the application. One hundred ninety students stated they did not know the lake's location on the university campus; these 190 students were selected to participate in the simulation.

Then, the type of operating system used by the mobile phone equipment of the 190 selected students was identified. 80 students had cell phones with Android operating system and the other 110 had iOS operating system. The 80 students who had cell phones with Android operating system installed the Ubícate USC application.

The 190 students were located at the campus's main gate and began searching for the lake, with 80 students using the Ubícate USC mobile app and 110 students traditionally asking people on campus. Each student was recorded for the time elapsed from the gate until the university lake.

5 RESULTS

5.1 Introduction to the results

The results from each application development stage met our objectives and requirements.

5.2 Results from each stage

Results from the Conceive Stage. The results from the first stage were the minimum requirements necessary for the application, as well as the architectural pattern of each requirement, as it may be observed in Tables 4 and 5.

Table 4. Functional requirements (FR)

ID	Requirement	Description	Architecture Pattern
RF1	List buildings, faculties, and common areas.	The application must list the information to the user of the buildings, faculties and common areas available to the educational institution.	Service-oriented architecture.
RF2	Show a 360 image of the place.	You should give a view of a 360 image of the buildings, faculties, and common areas that allows the user to have a site reference.	Service-oriented architecture.
RF3	List the events offered.	You must access the event repository service to list active events.	Service-oriented architecture.
RF4	Use the Google Maps API.	To show the map of the educational institution, the location of the user and give him a guide to get to the site.	Service-oriented architecture.
RF5	Show information on the sites of interest in each building.	Display information that allows the user to see the places of interest on each of the floors of the building.	Service-oriented architecture.
RF6	Nomenclature of the rooms.	It should show how the nomenclature of the rooms is structured.	Layers

Table 5. Non-functional requirements (NFR)

ID	Requirement	Description	Architecture Pattern
RNF1	Multiplatform	Must be available for iOS and Android operating system.	–
RNF2	SO version	Available for Android 4.4 or higher and iOS 9.0 or higher.	–
RNF3	Interoperability	With external services.	Service-oriented architecture.
RNF4	Maintainability	Be easy to maintain and update service information.	Layers
RNF5	Connection	The application requires an internet connection to access the services.	Service-oriented architecture.
NF6	Location	It must request location permissions from the user.	–

Results from the design stage. In the design stage, the results were case diagram provided in Figure 1 below.

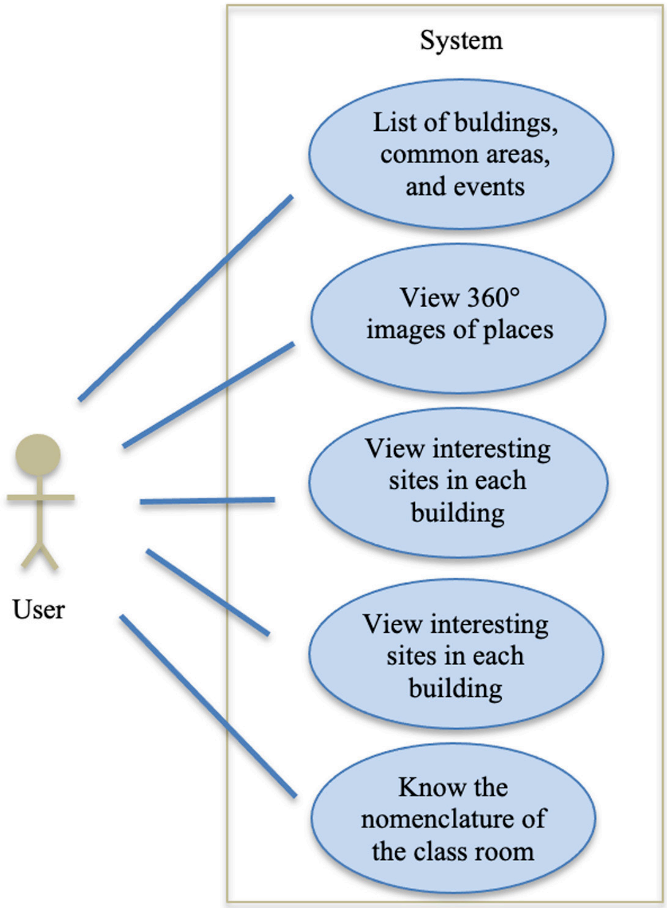

Fig. 1. Use case diagram

In addition, this stage also provided the design of the database tables, as observed in Tables 6 and 7.

Table 6. General model

Buildings / Faculties / Common Areas	
ID	String
Name	String
Icon	String
Color	String
LinkImage360	String
SitesOfInterest (Buildings Only)	Array<SiteInterest>

Table 7. Landmark model

SiteInterest	
Floor	String
Sites	Array<String>

Results from the Implement Stage. In this stage, the designs and user requirements were implemented, obtaining as a result the list of buildings, schools, departments, and common areas. They are presented in Figure 2.

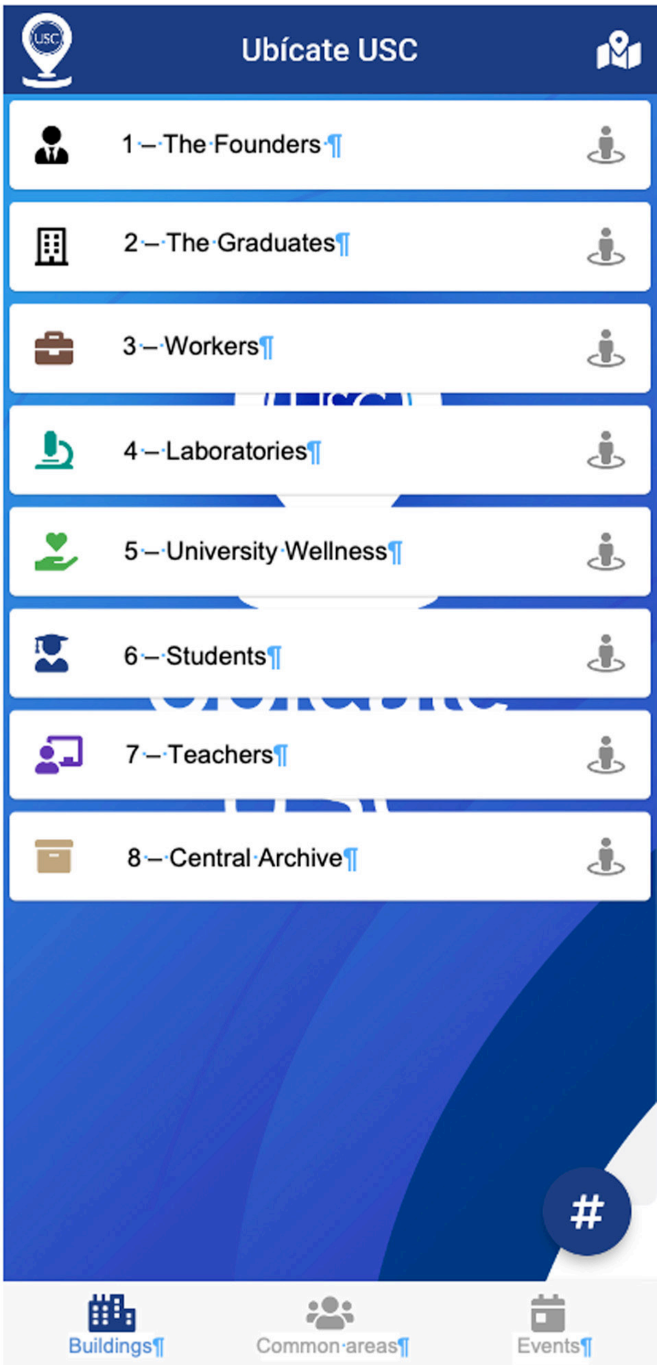

Fig. 2. List of buildings

In the module developed for the RF2 requirement, the implementation of the dependency that supports viewing 360 images was conducted. For its correct operation, images must be loaded into the cloud, thus preventing overloading the application. For these purposes, images are uploaded to a server and their request will be made through a Rest request. The results obtained are shown in Figure 3.

Fig. 3. 360 image

The results from the RF3 requirement were achieved through the consumption of the Peewah platform service, which is a campus-wide event repository. Here, the required information was displayed to the user. This is presented in Figure 4.

Fig. 4. Event list

For the RF4 requirement, the Google Maps API was consumed to obtain a campus map. User location was displayed, and the route was traced from the pedestrian entrance to Building 2 using the coordinates from Table 8. This is presented in Figure 5.

Table 8. Pedestrian entrance–building 2 coordinates

ID Coordinate	Coordinate (Lat, Long)
1	3.4034561142780864, –76.54699079204462
2	3.403437371930408, –76.54715306567478
3	3.403505647623739, –76.54725901292092
4	3.4034092584082094, –76.54731668040931
5	3.4034012259731483, –76.54745347305624

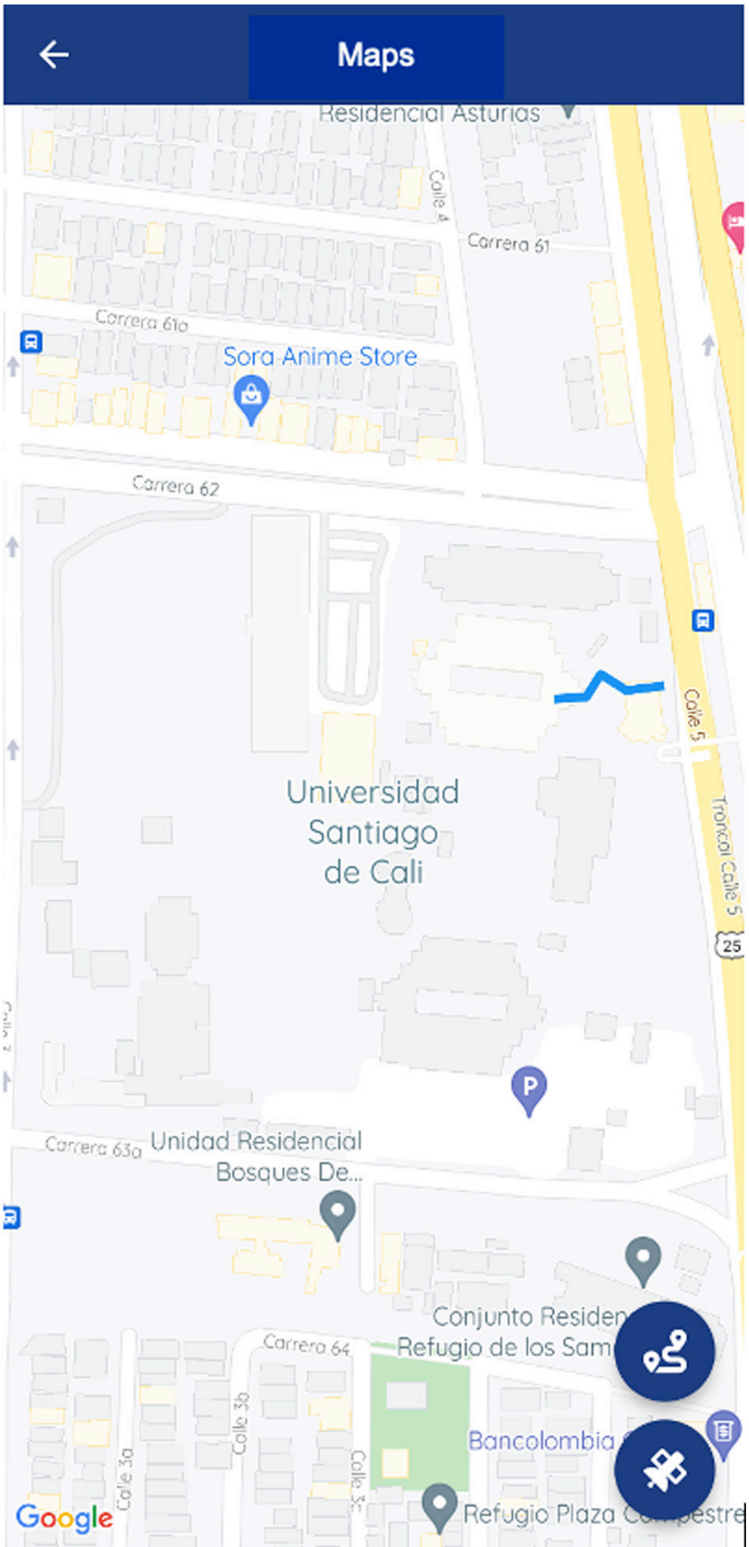

Fig. 5. Route

The results obtained for the module created as part of the RF5 requirement provide information on places of interest and landmarks using database information, as observed in Figure 6. For the RF6 requirement, room nomenclature is clearly displayed to the user. This is presented in Figure 7.

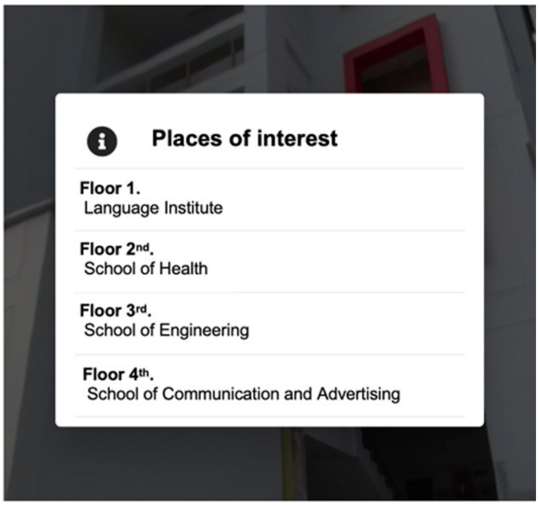

Fig. 6. Places of interest

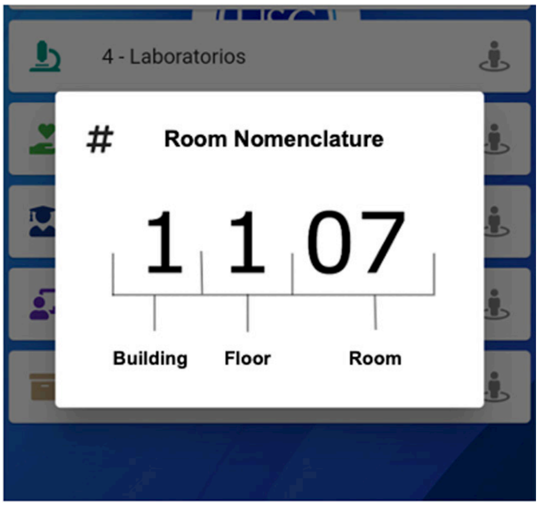

Fig. 7. Room nomenclature

Results from the operate stage.

Results of general test. After assessing the deployment of the application, we determine that this application tracks user location within the campus, which saves time, and provides users with information of upcoming community events. In addition, even when the application is still being tested by campus users, it helped users move around campus. This is evidenced as users provided positive references regarding the intended goals. Moreover, user feedback supports the continuous improvement of the application.

In 2018, 518 events were held with an average attendance of 70%, A fifth of the people who missed or did not arrive at an event stated that they had difficulty finding the place.

Unlike 2018 and already with the application in use, in 2022, 861 events were held, with an average attendance of 85%. 97% of people who had difficulties arriving or did not arrive declared that they did not install or did not use the application.

Results of location simulation. Upon completion of the simulation test, a survey was conducted of the 80 students who used the Ubícate USC APP, to know the opinion of users on the usability of the application [27]. The survey had five questions: Did you have any problems installing the application? 100% of the respondents had no problem installing the application on their phones. Do you consider that browsing through the APP is intuitive? 92.5% of respondents answered that navigation through the APP is intuitive. Do you consider that the information provided by the APP facilitated the location on the university campus? 97.5% considered that the application facilitated their location. Do you consider that the selection of campus places is appropriate for you? 95% of people answered that the selection of campus places in the APP is appropriate. Do you need additional knowledge to use the application? 100% of the people surveyed answered that they do not require additional knowledge to use the APP (Table 9).

Also, at the end of the survey, a section was added for people who wanted to make additional comments regarding the use of the application; 17 of the 80 people surveyed agreed with the following three comments: Very good application for new people at university, very easy to use and to locate in the university and very good application.

Table 9. Results of the 190 location simulation tests on the university campus, 80 people using the Ubícate USC APP and 110 people without using the APP

Item	Number of People	Time to Get to the Site in Minutes	Average Time in Minutes
Using APP Ubícate	44	1	1,45
	36	2	
Without using APP Ubícate	12	1	2,9
	48	2	
	16	3	
	24	4	
	3	6	
	7	7	

6 DISCUSSION

6.1 Introduction to the discussion

The following section will discuss the results from the previous section considering each development stage mentioned in the methodology.

6.2 Discussion of the results from the conceive stage

When assessing the requirements for the development of the mobile application, we observed that the application must be supported by both Android and iOS operation systems. In addition, it must feature good performance and provide access to device permissions. Since we currently use three types of applications (web, hybrid and native), we determined that this application must be native to request GPS permissions from the user. Consequently, we decided to use a relatively new framework, known as Flutter, which supports the creation of native applications for both operation systems, thus meeting expectations without neglecting the support that the application requires while in use.

6.3 Discussion of the results from the design stage

Initially, the design of the application focused on the application working offline to provide the service independently of whether the user has internet access or is connected to the university network. However, the application had to be an online application to access event information stored in the Peewah platform. For this reason, and using internet connection to optimize application bandwidth usage, the 360 images were migrated to the cloud. This benefits users by making the application downloadable on low-resource devices. Finally, event information is stored in a cloud-based database so that it can be constantly updated without requiring new application releases.

6.4 Discussion of the results from the implement stage

In the implementation stage, the application was developed using the Flutter framework and based on the previous defined assessments and requirements. For its main purpose, which is tracking user locations within the campus at educational institutions, three service providers were considered: OpenStreetMaps, MapBox, and Google Maps. However, when integrating with OpenStreetMaps not much information was found, which made integration difficult. For this reason, we discarded this option. The MapBox provider included a direct library, but, even when the documentation was good, system errors caused the application to occasionally fail. Finally, we decided to implement Google Maps since their documentation is accurate. In addition, Google provided sufficient support, which facilitated implementation, and provided different routes that users may follow to their destinations based on their current location.

6.5 Discussion of the results from the operate stage

General test results discussion. In the operation stage, the results from the survey responded by 149 users evidenced that, regarding application usability, several users suggested that adding a voice chat feature may provide greater help to users. Another requested feature was adding business hours and contact numbers for the different schools and departments within the campus. The application can also be expanded to other sites by collecting data for mapping routes, images, and points of interest. According to institutional statistics, non-attendance at academic events decreased by 15%. This information was obtained by comparing the number of registrations and the people who registered their arrival at the respective event.

Location simulation results discussion. According to the results of Table 9, it is observed that the use of the APP during the simulation of location on the university campus allowed the reduction of the average time by half, as compared to the time used in finding the location without the use of the APP.

Additionally, the location times data with the APP are more homogeneous with respect to the location time data without the use of the APP, data with greater dispersion. This can be explained by relying on relative knowledge of other people's location on campus when APP is not used.

The survey results regarding the perception of end users about the application are satisfactory, given that students enjoy using mobile devices as an information tool.

7 CONCLUSIONS

7.1 Conclusions from the conceive stage

When conducting the Conceive stage, the MVVM design pattern provided us with a clean and understandable code. In addition to separating the business logic from the user's view, this design pattern was very useful in determining the architectural pattern associated with each requirement. It is a good practice because it allows developers to understand how the requirement must be executed.

7.2 Conclusions from the design stage

We were able to comply with a functional application design since it provides the information required for users to track their own location within campus. In addition, it fosters usability since it has a minimalist and understandable design, with few buttons so as not to confuse the user. The application is maintainable since new spaces or events can be added and modified without affecting the operation of the application.

7.3 Conclusions from the implement stage

In the implementation stage, we concluded that several service providers can be used to meet the requirements. However, as evidenced for maps and the Flutter framework, not all of them feature the same characteristics or the same integration capabilities. For this reason, we decided to use a single ecosystem, such as the Google Cloud Platform, to avoid compatibility issues between providers and services.

7.4 Conclusions from the operate stage

General Test Conclusion. In the last stage, we conducted tests with different users, ensuring that the application meets the objectives defined and taking into account user feedback regarding features that they would like to see implemented in future updates and to expand the services offered.

Mobile applications change the perspective of the academic community. When you are going to receive training, location is very important. This first positive impact is decisive to arrive with a good attitude towards an educational process. It is a good start to promote STEM activities in the classrooms [28].

It is essential to coordinate some tool installation campaigns to get users to empathize with the application and to know its handling, and to visualize the use of the devices as something simple [29] [30].

Location Simulation Conclusion. With the simulation of location on campus using the APP, the reduction of location time for the user was verified, achieving more homogeneous times. The results of the perception survey on the use of APP are satisfactory, and the young public enjoys using mobile devices as a tool to solve their needs.

8 FUTURE WORK

This research project focused on providing a solution to the problem of locating users through GPS and visual aids, but many open lines remain for development in future research projects [31].

8.1 Future work for the conceive stage

We propose assessing the possibility of conducting a study of the WiFi devices distributed around the campus to take advantage of this technology for locating users inside buildings, as well as combining this technology with others, such as Bluetooth, and device sensors that may improve data accuracy.

8.2 Future work for the design stage

We propose mapping the campus using 3D technology to enrich the design of the application, thus providing an immersive experience to users, and allowing them to make virtual tours around the campus, in addition to obtaining detailed information on each available space.

8.3 Future work for the implement stage

We propose assessing the integration of augmented reality in the development of the application, thus leveraging the benefits from the Flutter framework to access the full potential of the device, and combining GPS, WiFi, Bluetooth, geomagnetism and other technologies to provide a better user experience and a more precise location. In addition, a virtual assistant is suggested in case users do not understand well some of the application features. Also, programming workshops explain the application via streaming, using the most popular tools such as ZOOM, Google Meet and Microsoft Teams [32].

We proposed to proceed with access to the installation of the application for other platforms.

The Ubícate USC APP uses the Google Maps platform. This will allow the technological advances of this platform, with the use of artificial intelligence, to be scalable in the future to the APP. Gloogle Maps will implement Indoor Live View incorporating augmented reality and improving location accuracy inside buildings. In this way, campus places can be attached to the interior of blocks and buildings, with greater complexity of location.

8.4 Future work for the operate stage

We suggest implementing Fastlane for continuous delivery practices, as well as continuous integration testing frameworks, such as Travis CI or Cirrus CI, to detect failures as soon as possible and improve delivery times to the user.

We recommend relaunching the application, especially at the beginning of the semester for the new academic community.

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11 AUTHORS

Carlos Andrés Tavera Romero is currently a full-time professor at the Faculty of Engineering of the Santiago de Cali University. He is the coordinator of the research line for Computer Systems Development of the COMBA R&D research group (E-mail: carlos.tavera00@usc.edu.co). His research interest includes Information Systems Development, Information Technologies and Software Engineering.

Patricia del Rosario Segovia de Maya is a full-time professor in Programming at the Faculty of Engineering of the Santiago de Cali University (E-mail: patricia.segovia00@usc.edu.co). Her research interest includes pedagogy, TIC and Information Systems Development. She is currently a researcher in the COMBA R&D research group.

María Fernanda Díaz Velásquez is a full-time professor of the Electronic Engineering program and a researcher in GIEIAM research group at the Faculty of Engineering of the Santiago de Cali University (E-mail: maria.diaz20@usc.edu.co).

Diego Fernando Pérez Carvajal is a systems engineer and research assistant for the COMBA R&D research group at the Faculty of Engineering of the Santiago de Cali University (E-mail: diego.perez02@usc.edu.co).